Automated Identification and Characterization of Landforms on Mars

Tomasz F. Stepinski
Lunar and Planetary Institute

Collaborators:

Wei Luo

Erik Urbach

Ricardo Vilalta

Students:

Brain Bue

Ian Molloy

Michael Mendenhall

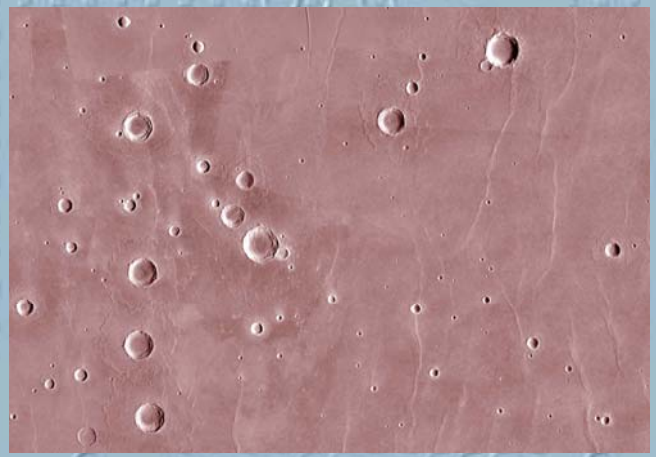
Soumya Ghosh

Will Pittman

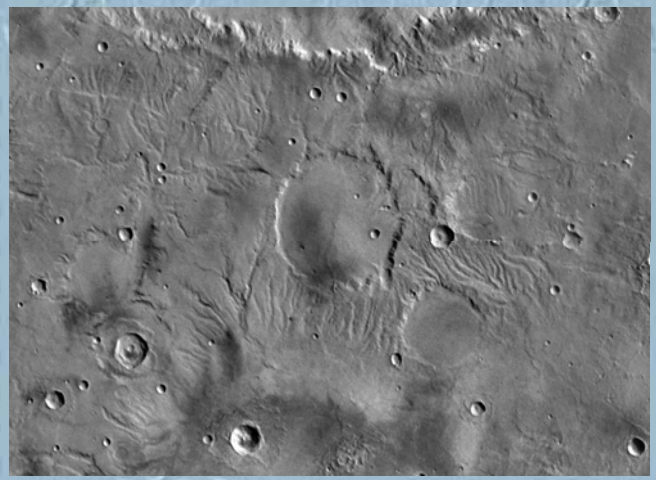
Two types of automatic mapping on Mars

Survey of specific landforms

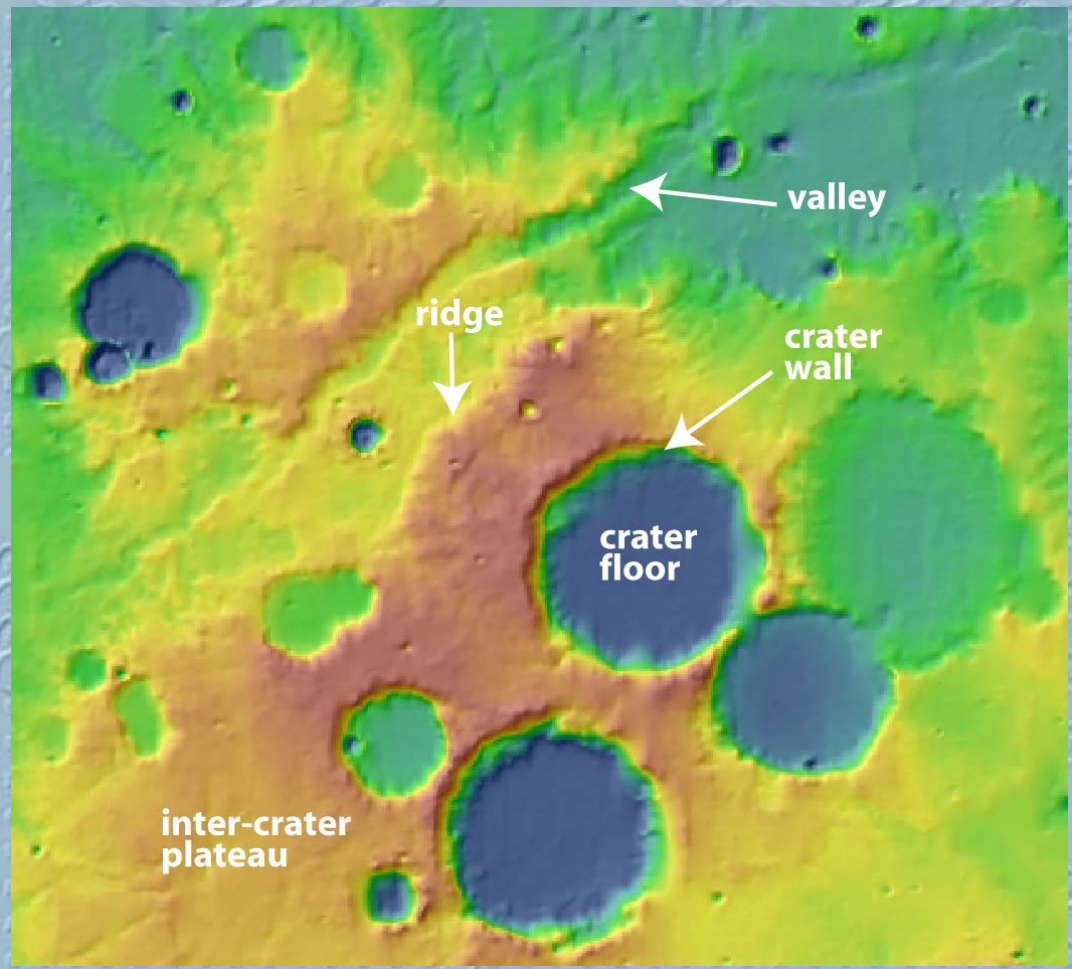
Impact craters



Valley networks *



Thematic (categorical) mapping **



Computational elements

- Terrain analysis
- Image processing
- Feature detection
- Machine learning

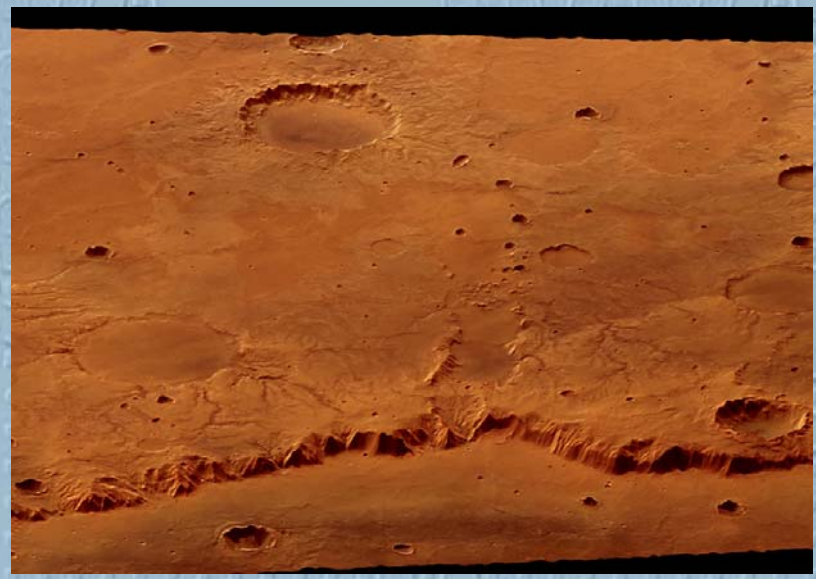
Mapping craters

Machine identification of craters from topography.

- **Overview: Towards global catalog of craters > 3 km.**
- **Focus on Southern hemisphere**
- **Application to distribution of ground water**

Machine identification of sub-kilometer craters from images.

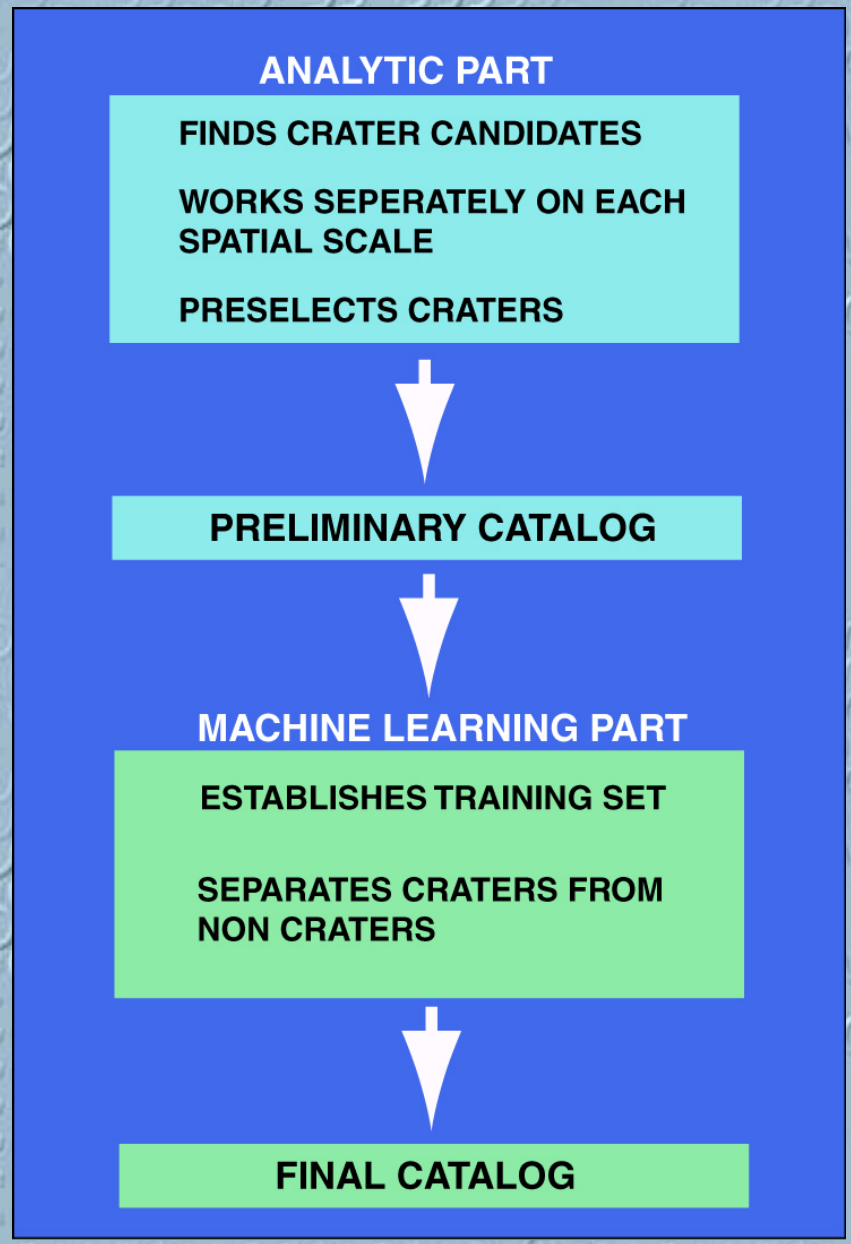
- **Overview of previous research**
- **New algorithm**
- **An example using HRSC image**



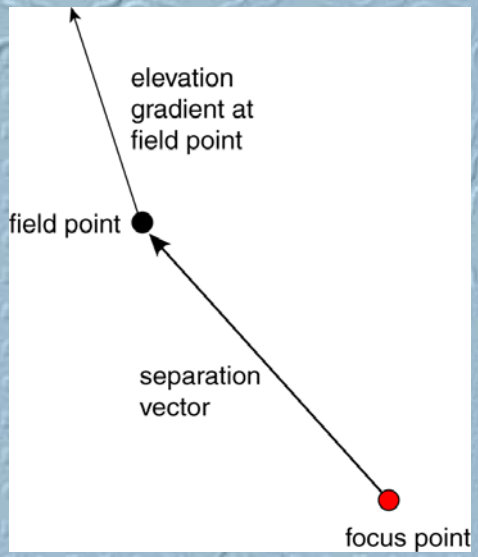
Algorithm for identification of craters from topographic data

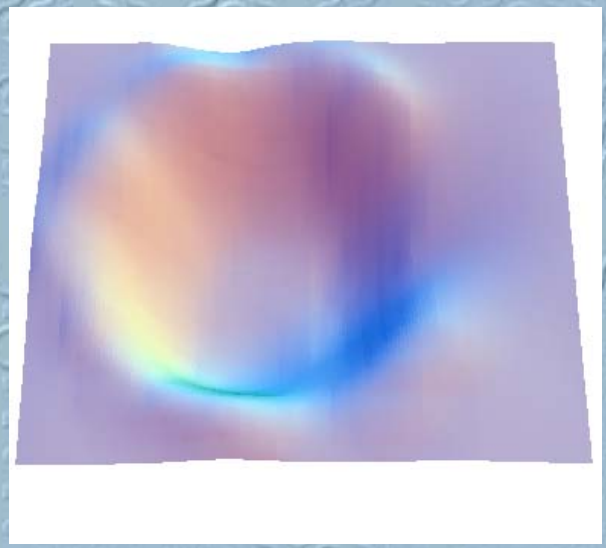
Design criteria:

- Robust, works well on all types of Martian surfaces.
- Fast, permitting generating a catalog of craters over the entire Martian surface.
- Scale-independent, can be applied to other topographic datasets.
- Simple, can be offered as a download.

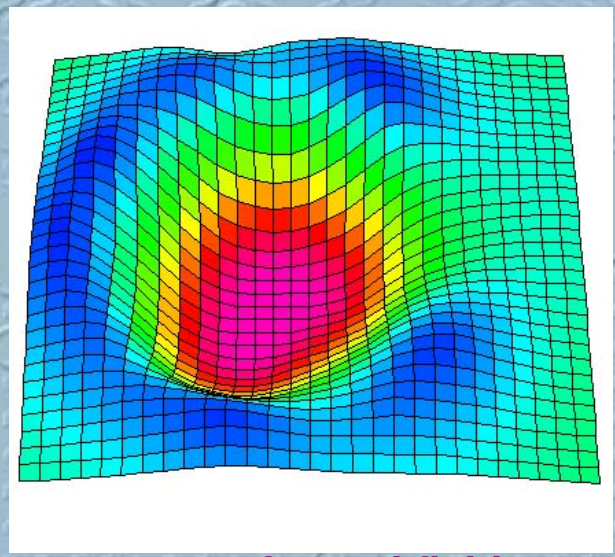


How it works? C-transform algorithm

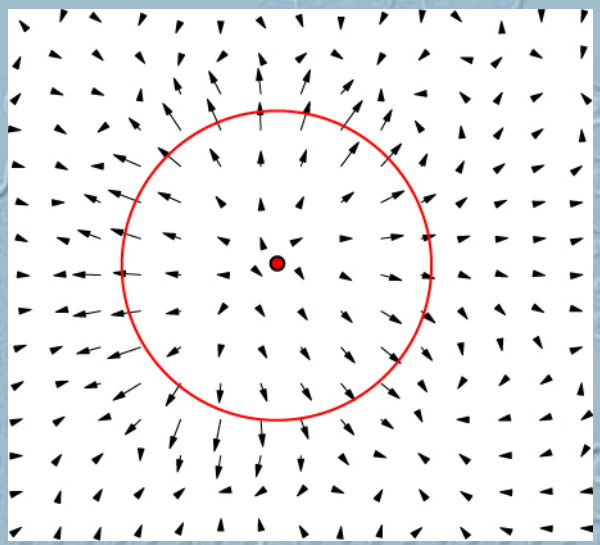




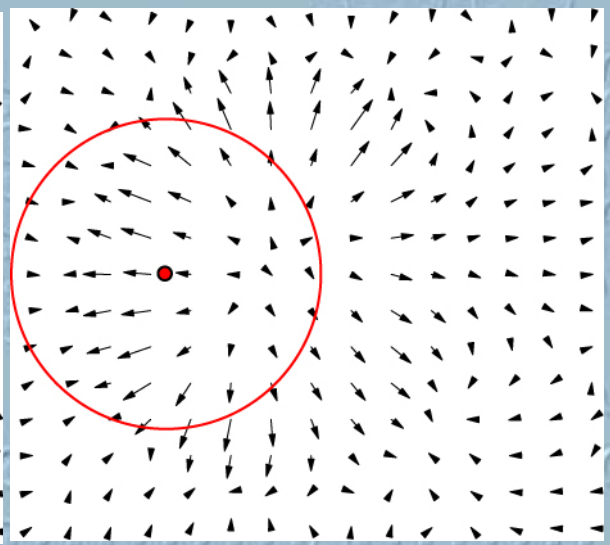
Elevation field



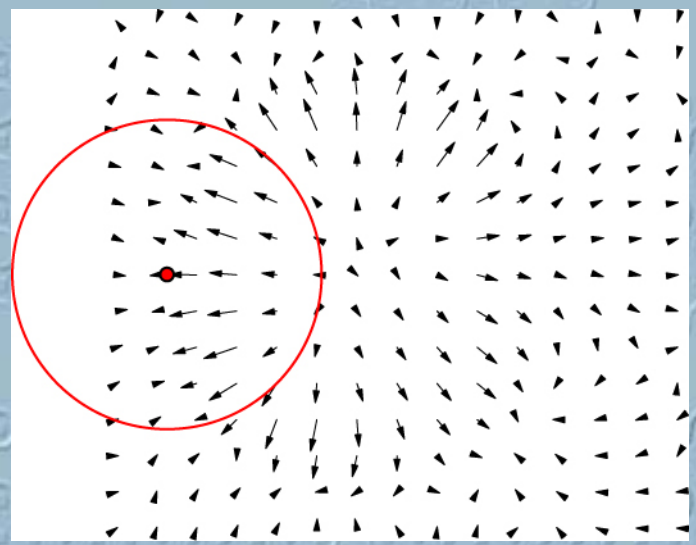
Transformed field



Focus point in the center of the crater (++)

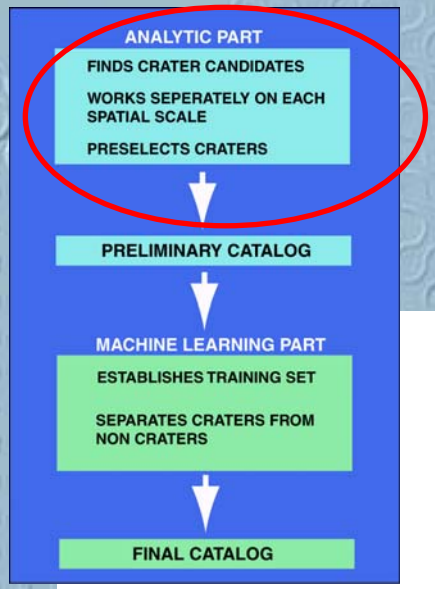


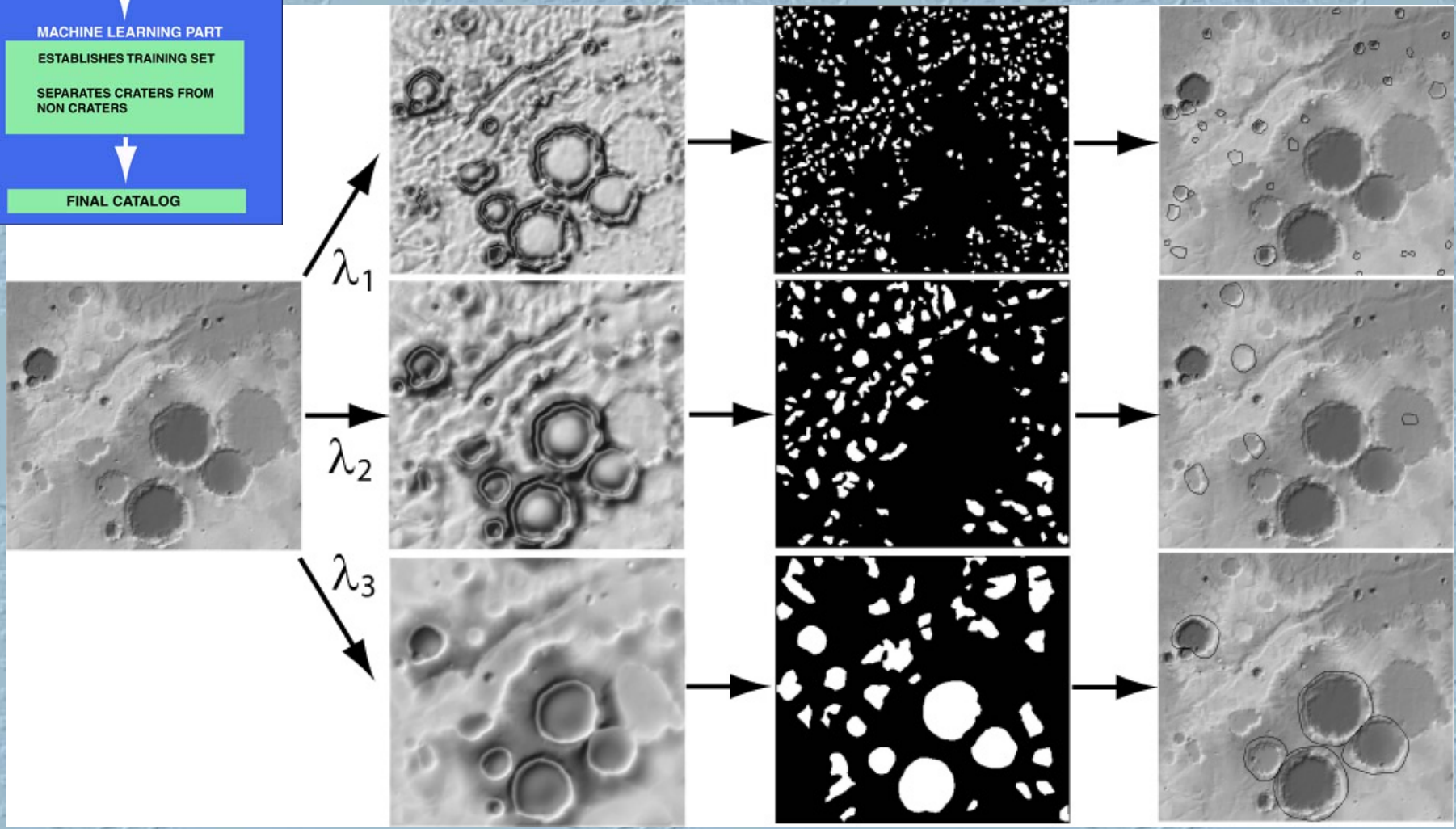
Focus point on the wall of the crater (+)



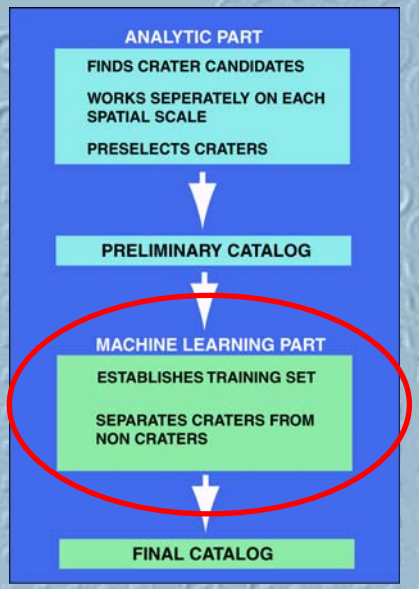
Focus point outside the crater (-)

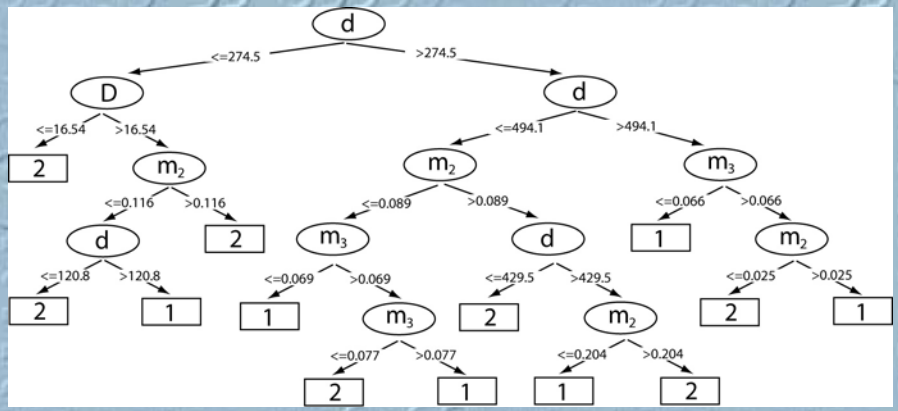
Finding crater candidates



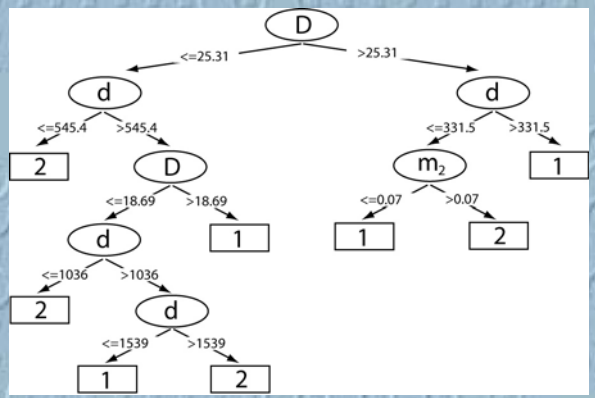


Cataloging Craters





Decision tree for scale #2



Decision tree for scale #3

Attributes:

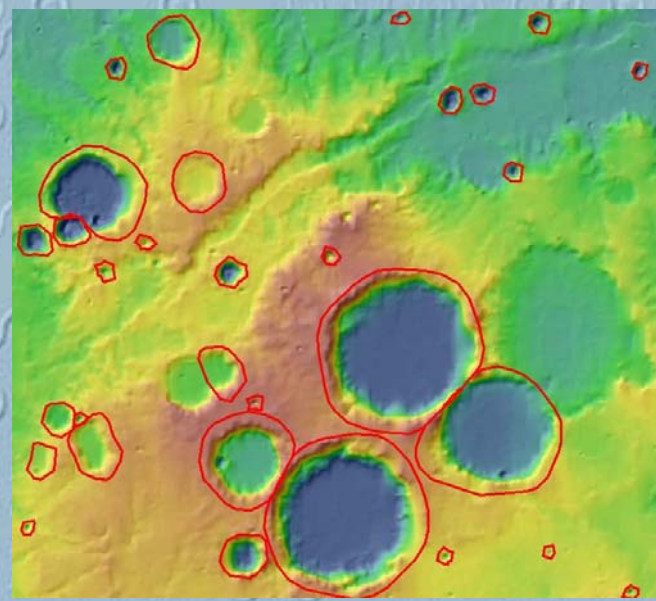
1) Diameter
2) Depth
3) Depth/Diameter
4) First shape descriptor
5) Second shape descriptor

Training set:

Scale #1 5970 examples
Scale #2 1010 examples
Scale #3 431 examples

Catalog contains:

1) Coordinates
2) Radius
3) Shape descriptors
4) Depth

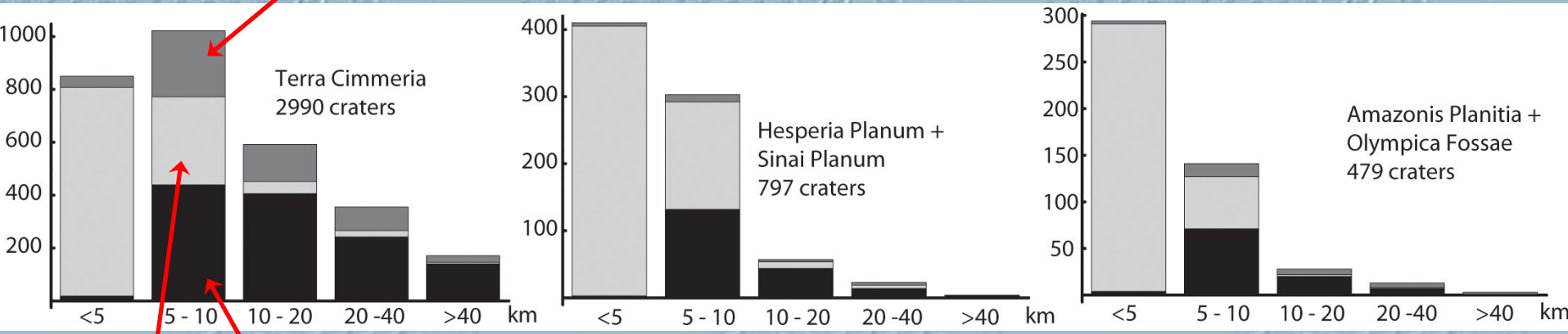


Testing our algorithm: automatic vs. manual

Site Name	Location Left(E), Right(E) Top(N), Bottom(N)	Area 10^6 km^2	craters AutoCrat	craters Barlow	craters matched	craters AutoCrat only	craters Barlow only
Terra Cimmeria 1	114.0, 141.4 -7.58, -18.42	1.0	734	466	336	398	130
Terra Cimmeria 2	117.4, 145.4 -17.0, -28.4	0.98	748	520	387	361	133
Terra Cimmeria 3	117.4, 145.4 -26.6, -38.6	0.92	662	457	313	349	144
Terra Cimmeria 4	117.4, 145.4 -36.5, -47.5	0.73	300	348	209	91	139
Hesperia Planum	107.1, 118.5 -17.0, -29.6	0.44	305	119	102	203	17
Sinai Planum	261.5, 278.6 -10.3, -29.7	1.0	468	101	94	374	7
Amazonis Planitia	195.0, 210.0 30.0, 15.0	0.79	153	66	47	106	19
Olympica Fossae	240.0, 255.0 30.0, 15.0	0.79	296	67	56	240	11
total		6.65	3666	2144	1544	2122	600

Testing our algorithm: automatic vs. manual

Craters present only in manual catalog

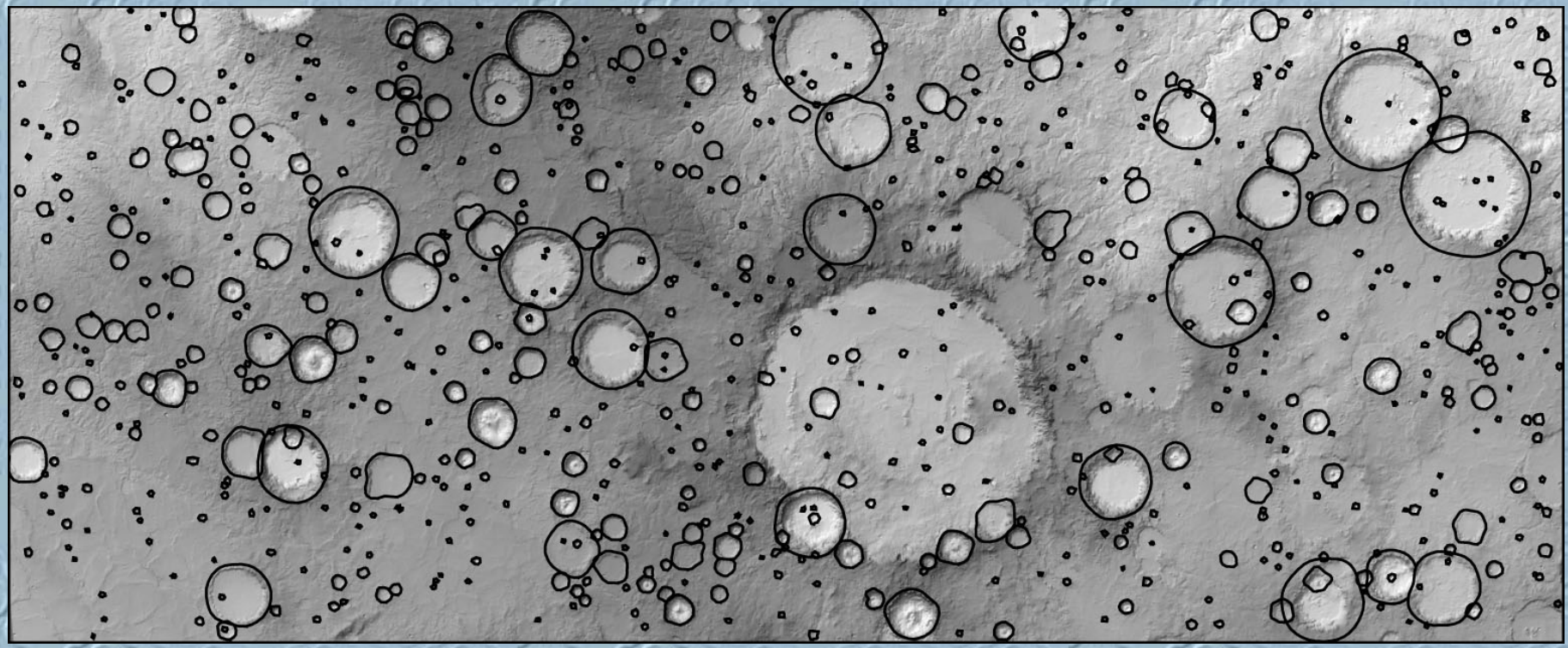


Matched craters

Craters found only by the AutoCrat

Testing our algorithm: Visuals!

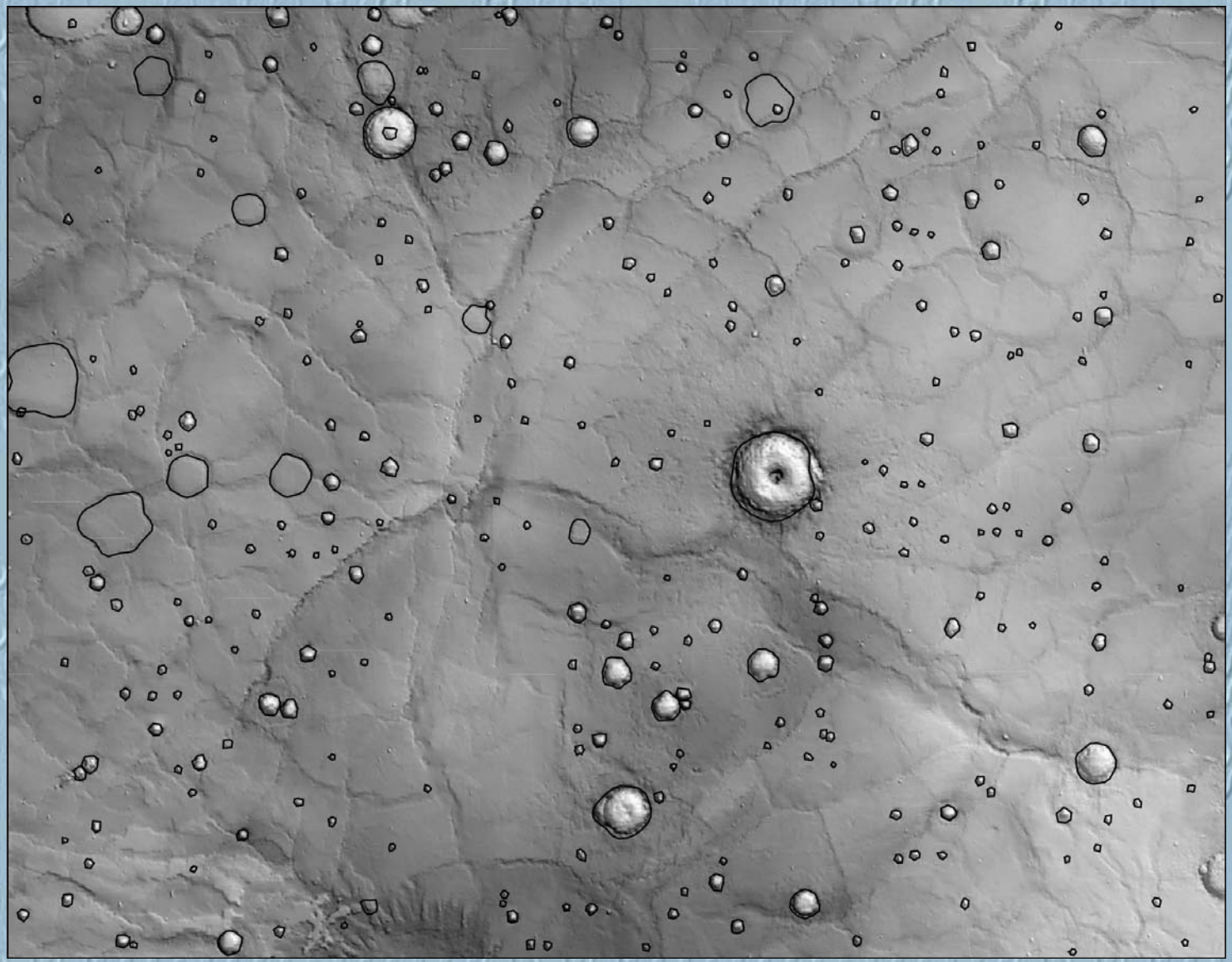
~ 1700 km



Heavily cratered Noachian terrain

Testing our algorithm: Visuals!

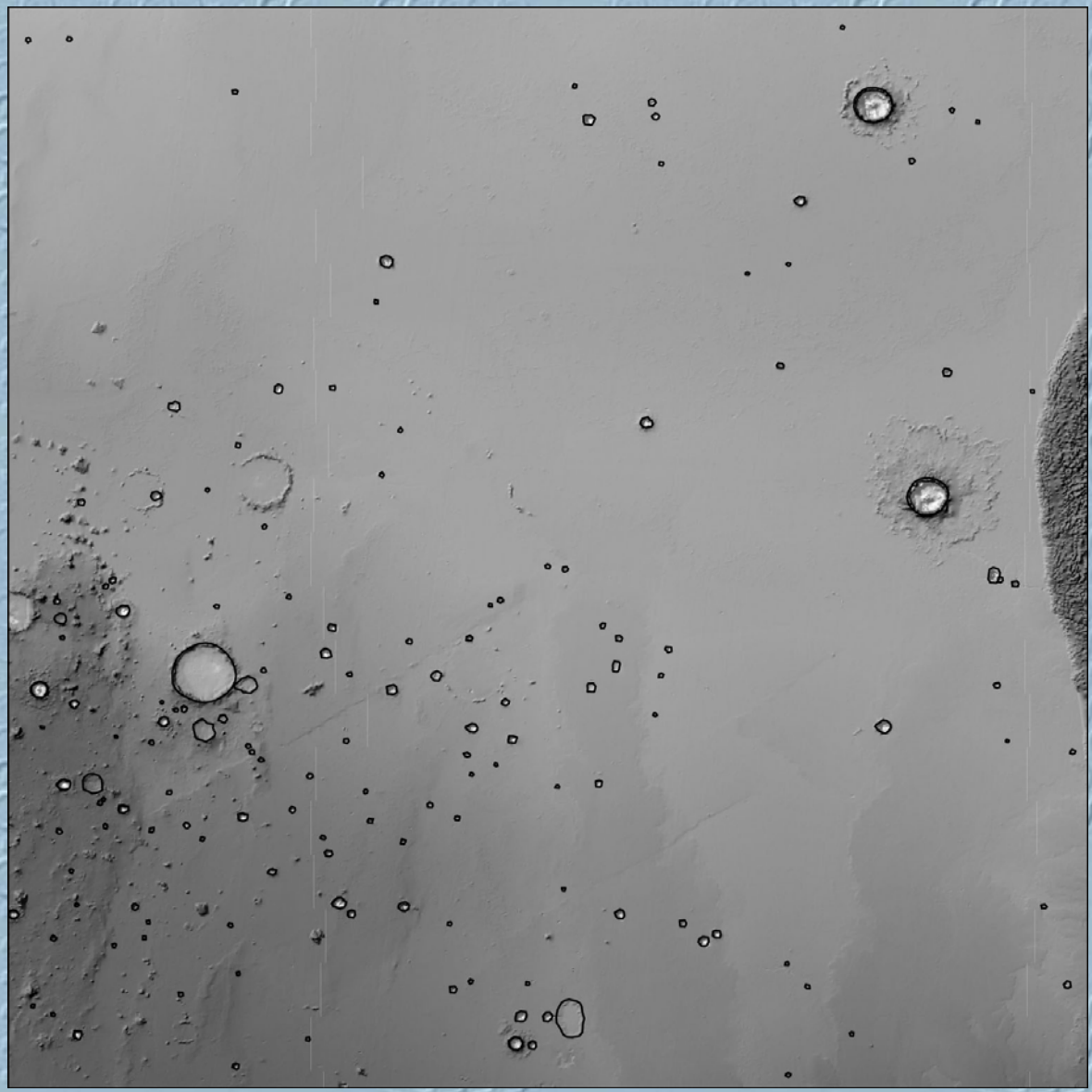
~ 600 km



Less heavily cratered Hesperian terrain

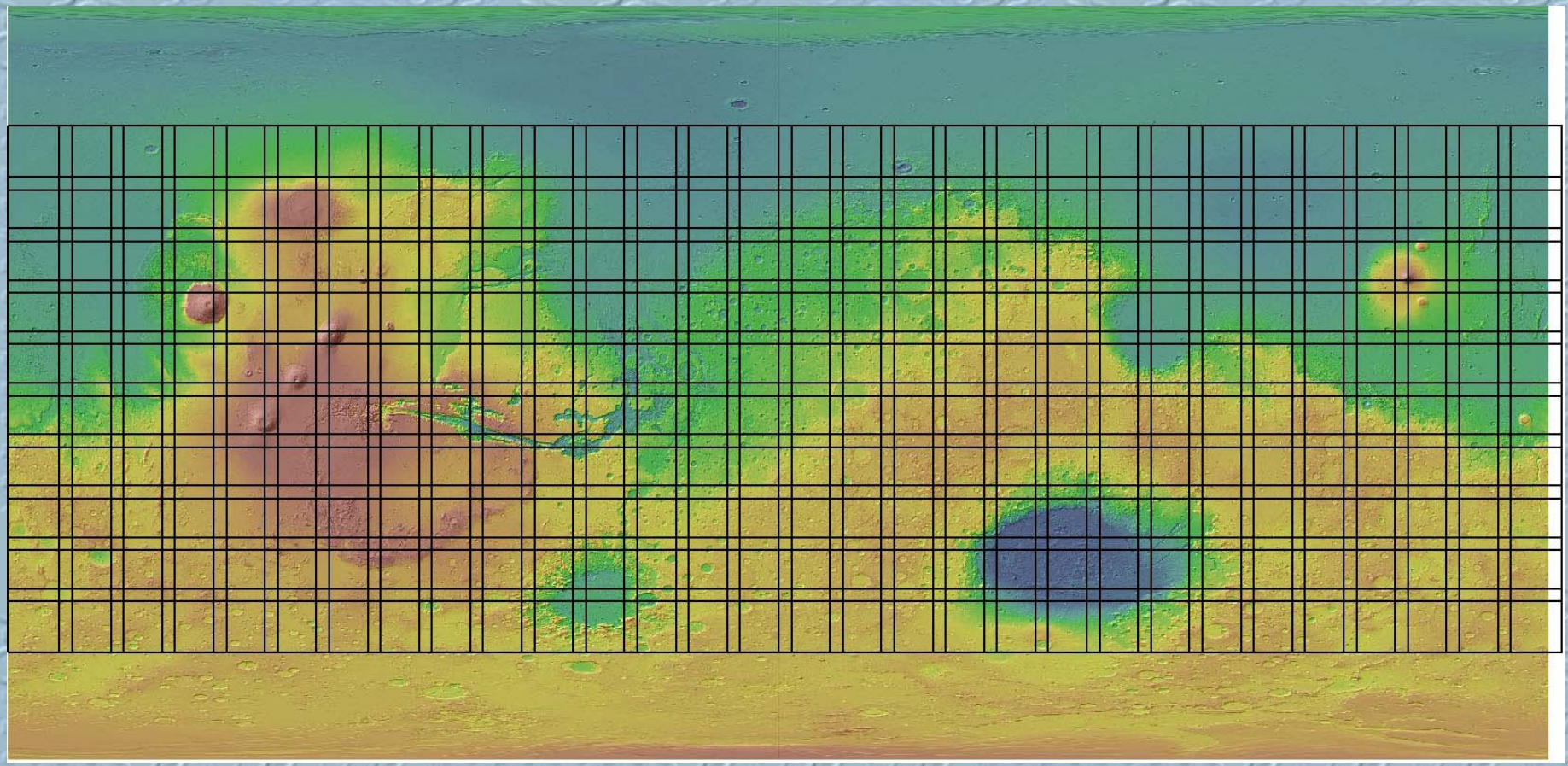
Testing our algorithm: Visuals!

~ 900 km



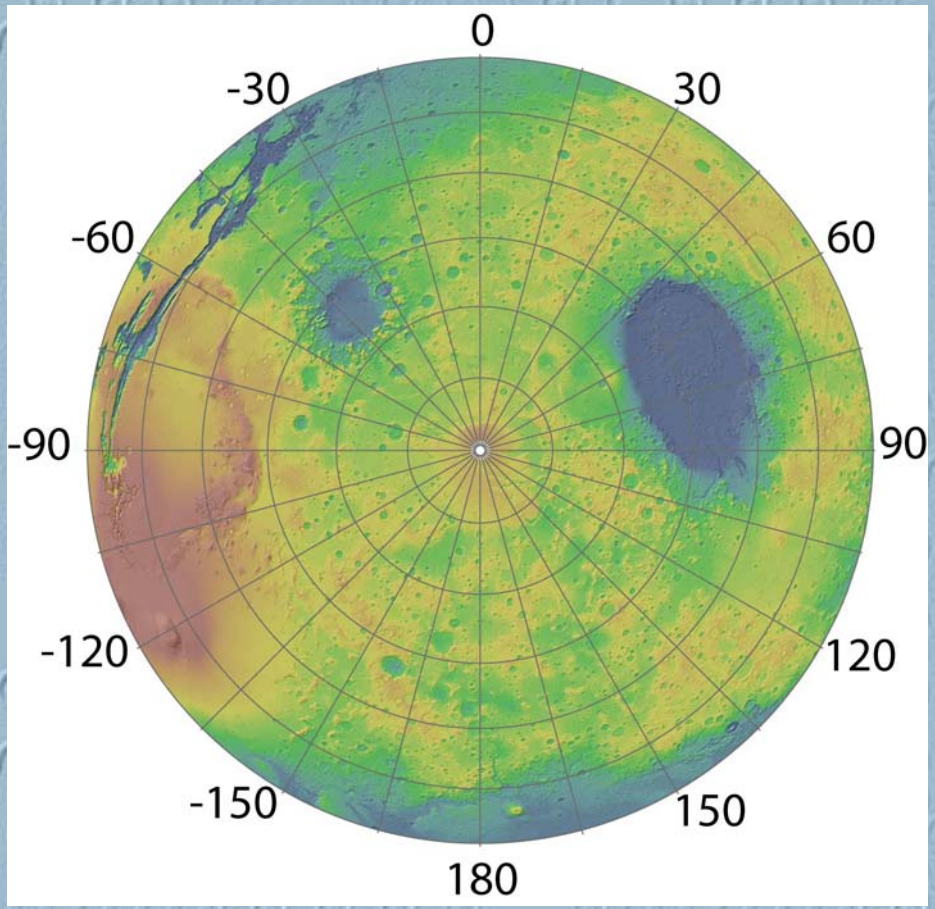
Lightly cratered Amazonian terrain

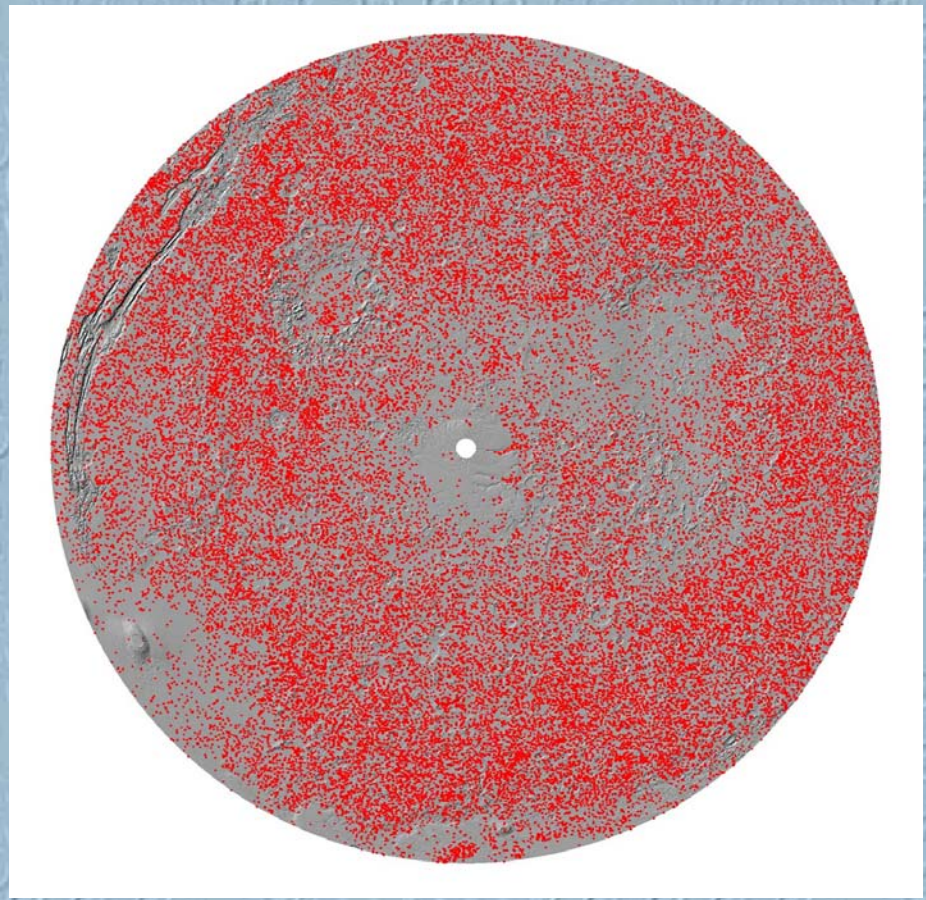
Global cataloging of Martian craters



300 overlapping “equatorial” tiles
Additional polar tiles

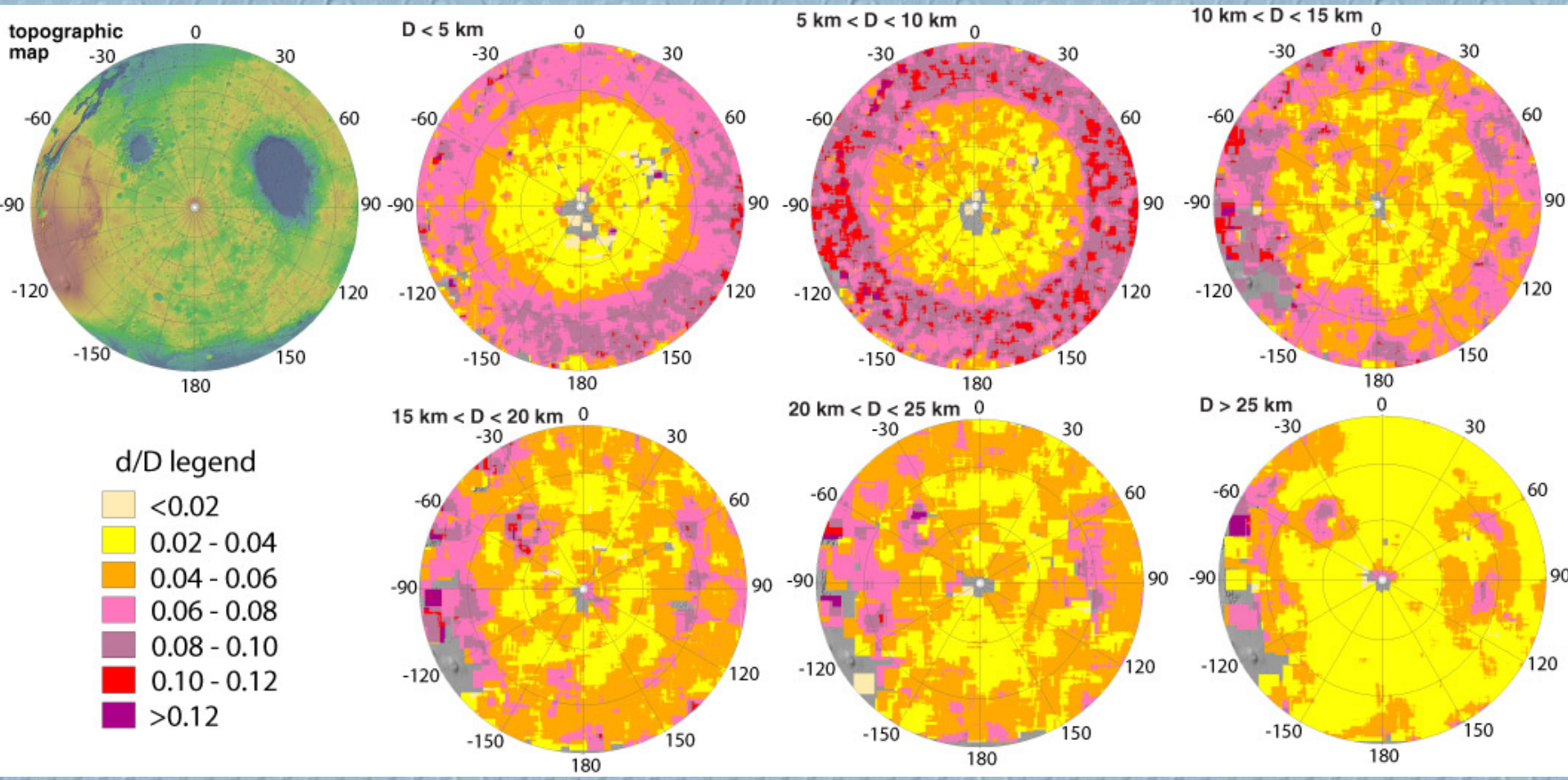
Application: mapping craters depths in Southern hemisphere



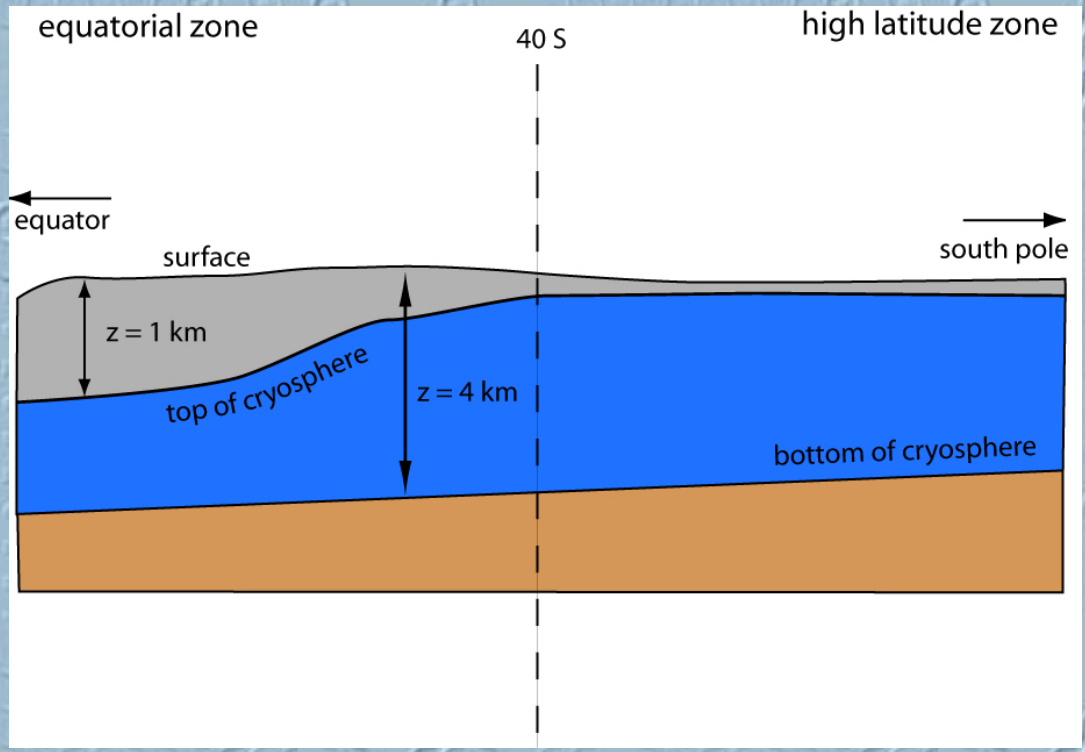


45,556 identified craters

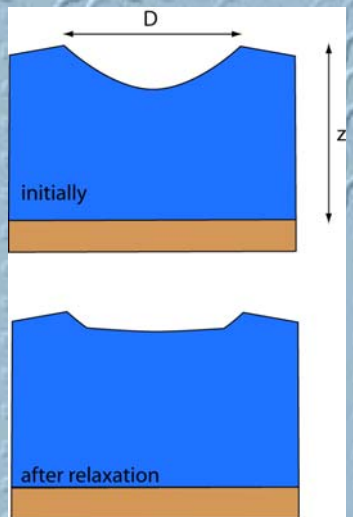
Application: mapping craters depths in Southern hemisphere



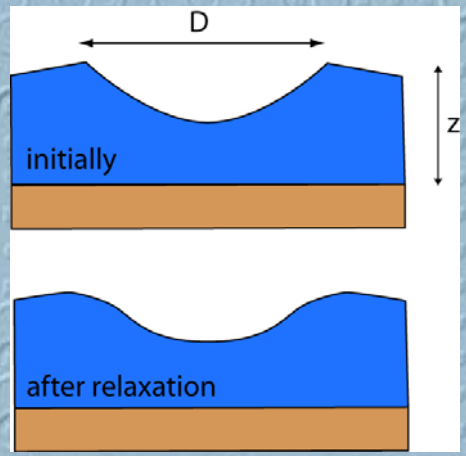
Implications for spatial distribution of ground ice



Viscous relaxation of craters emplaced in ice

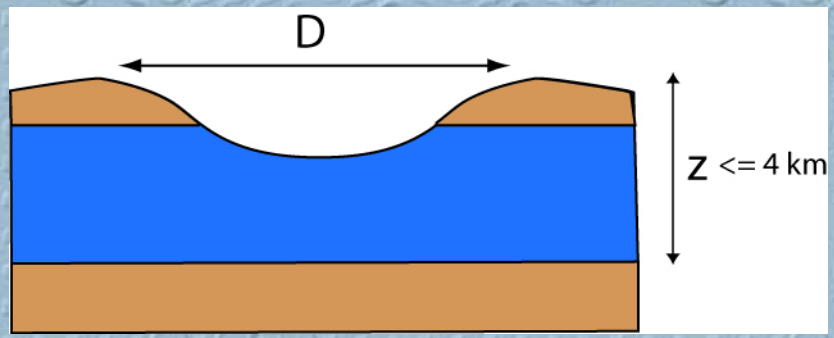


Large z/D regime: Dominant modification: raising of crater floor
d/D value: <u>decreases</u>

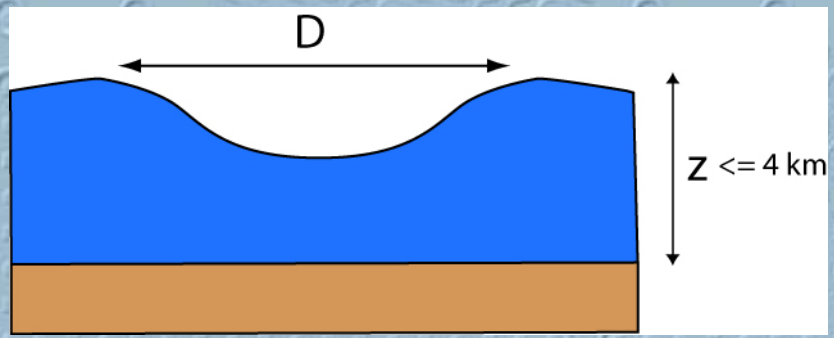


Small z/D regime: Dominant modification: rounding off crater rims
d/D value: <u>only small decrease</u>

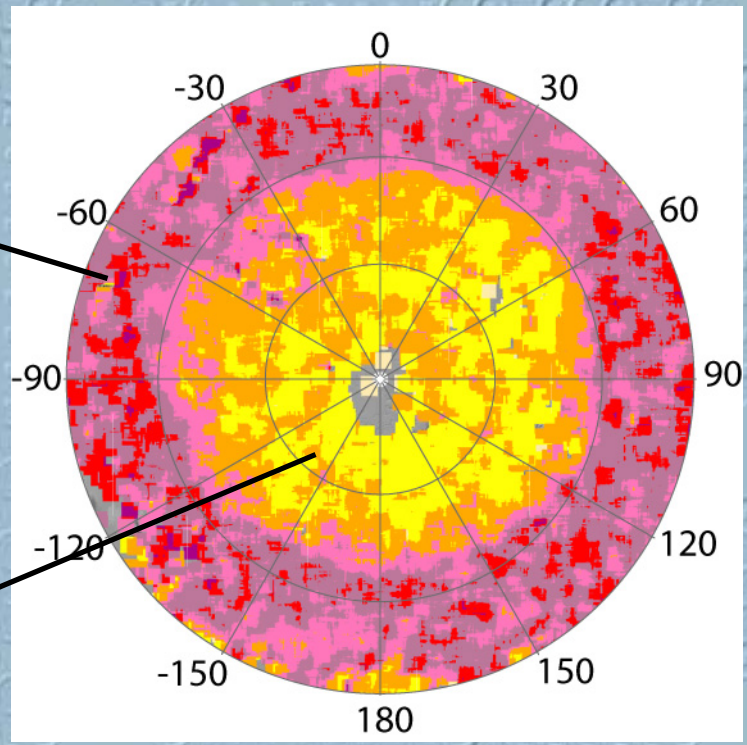
Implications for spatial distribution of ground ice



Equatorial zone



High latitude zone

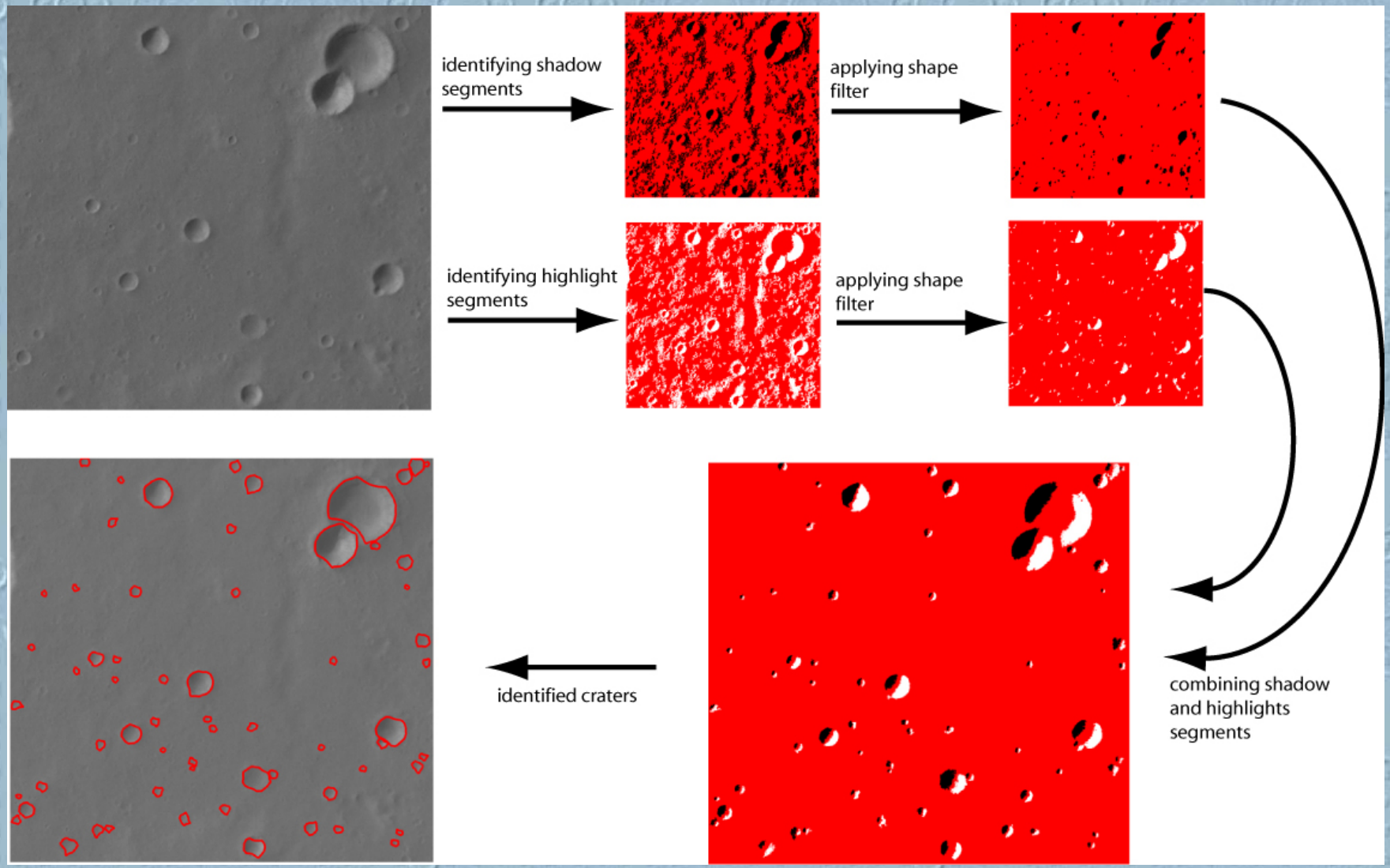


Summary for mapping craters from topography

- Mapping code is in the public domain and can be downloaded from http://cratermatic.sourceforge.net/. It has been downloaded 116 times.
- The global catalog of Martian craters will be delivered to USGS Planetary GIS Web Server (PIGWAD) by November 2008.
- Significant new planetary research will be done using this catalog.
- Mapping code can be reused with other topographic dataset for Mars, Moon and Mercury.

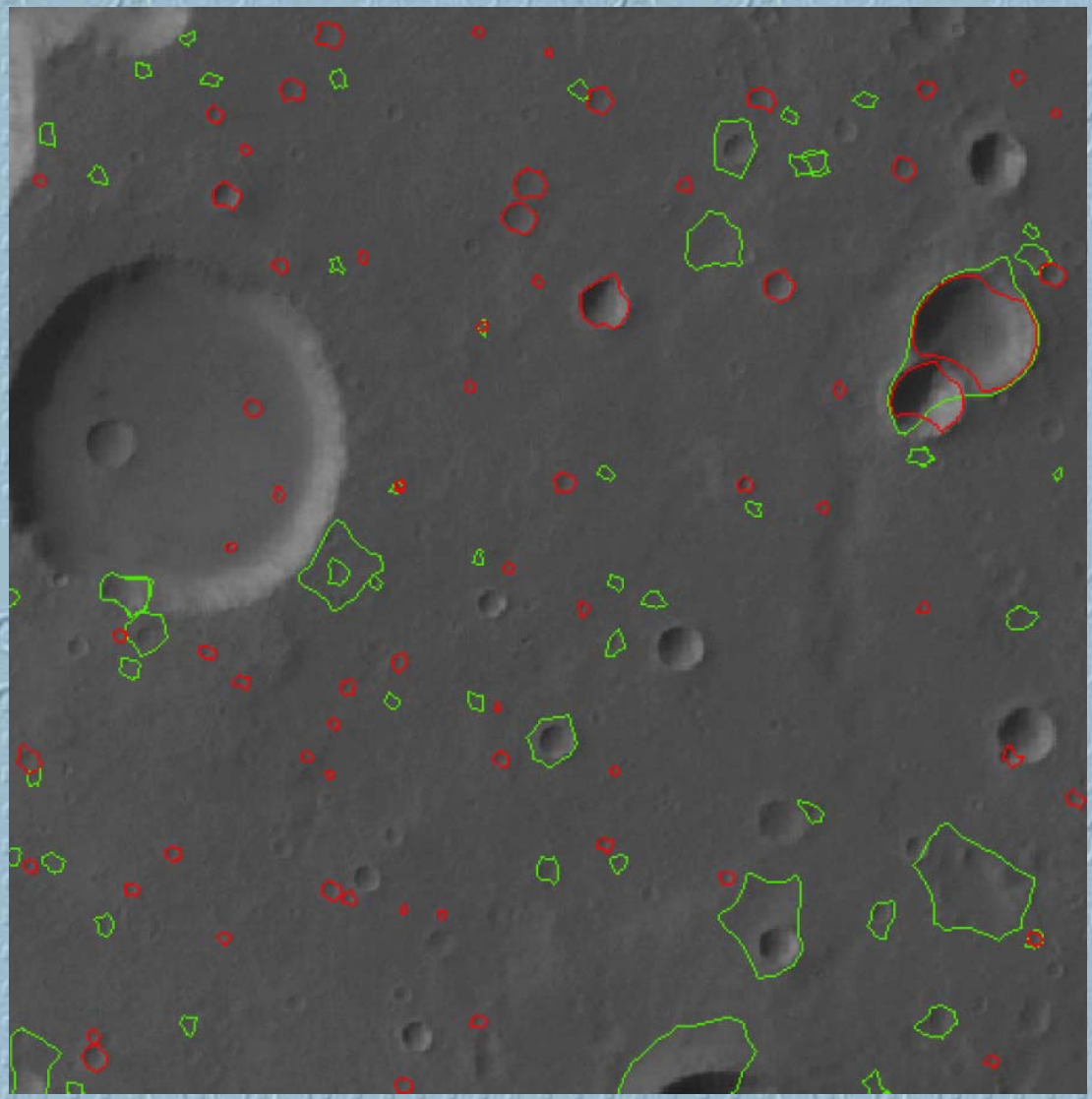
Machine identification of sub-kilometer craters from images

An idea behind our algorithm



Testing an algorithm for cataloging sub-kilometer craters

21 km

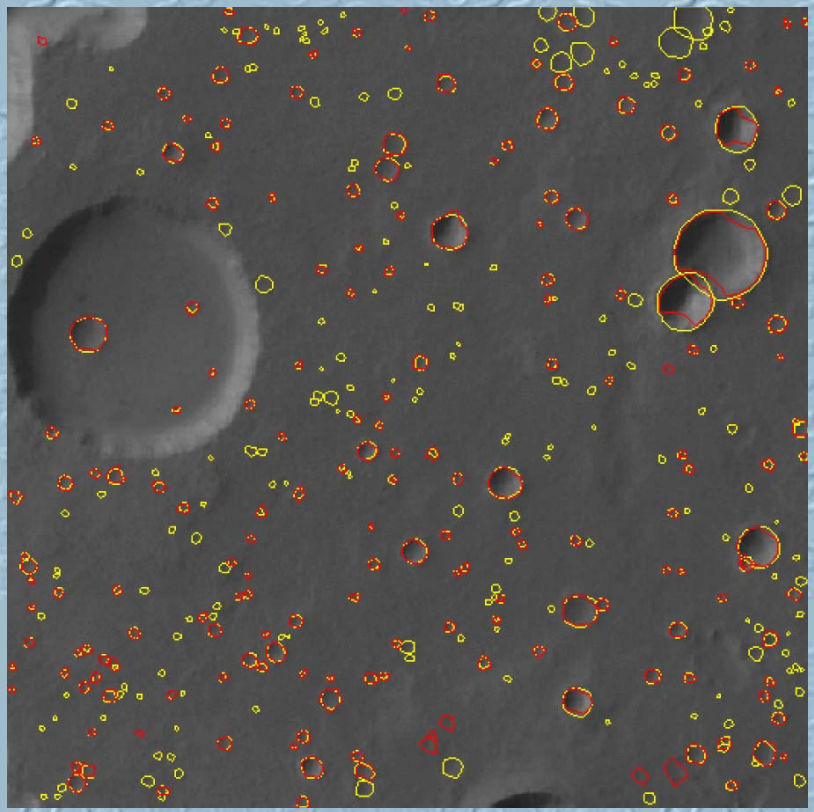


Training shapes:

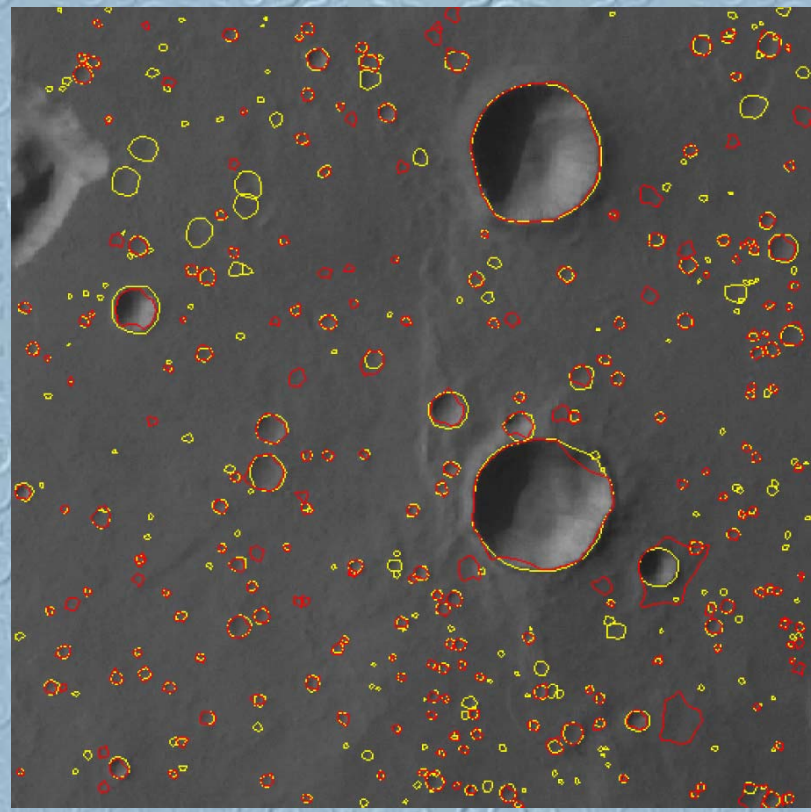
68 true craters

58 non craters

Testing an algorithm for cataloging sub-kilometer craters



Training site



Test site

Quality Factors:

D= 100 TP / (TP+FN) detection percentage

B= FP / TP branching factor

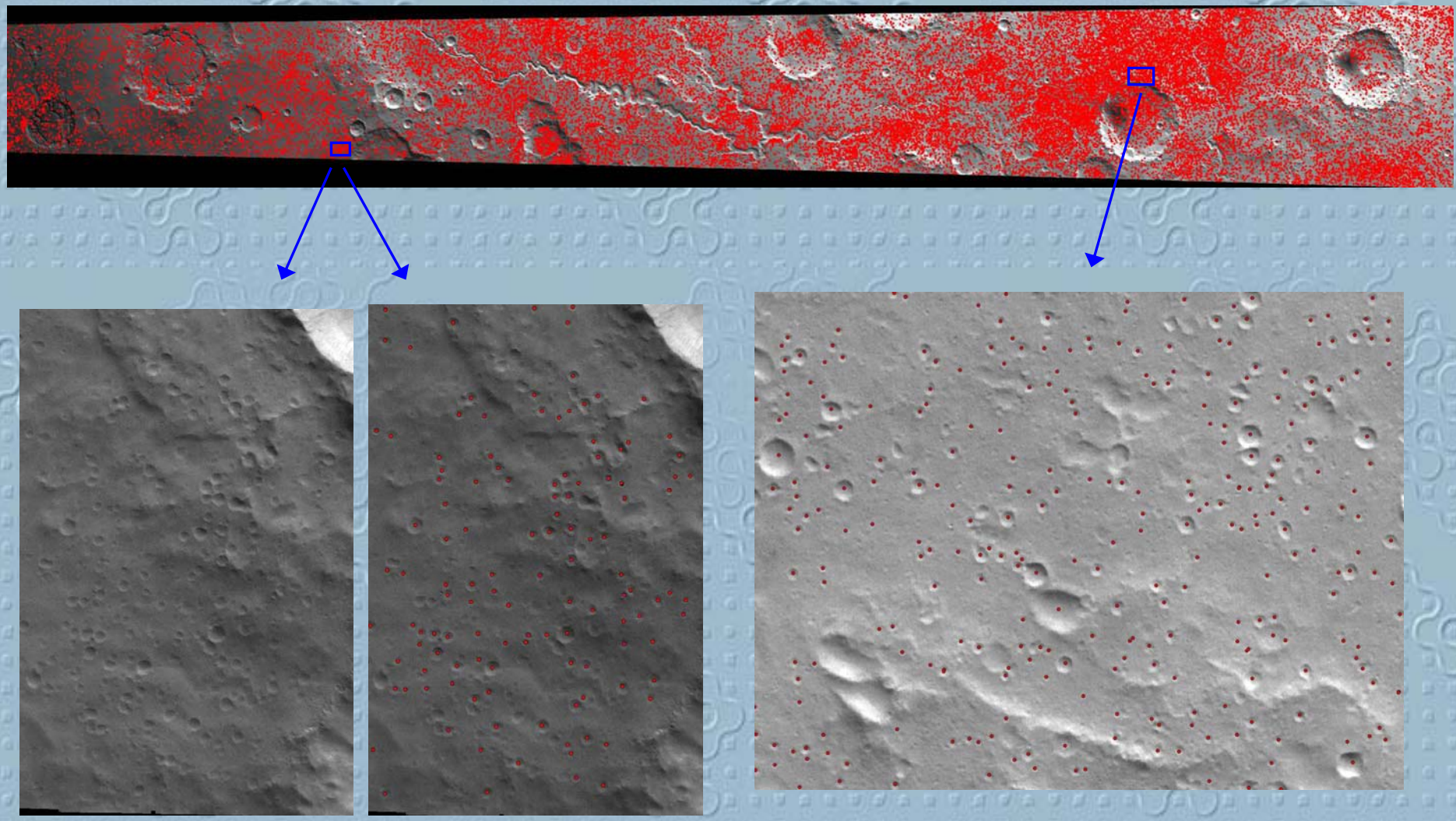
Q= 100 TP / (TP+FP+FN) quality percentage

	D	B	Q
Training site (all)	49.9%	0.06	48.5%
Training site (D ≥ 200m)	70.8%	0.09	66.5%
Test site (all)	55%	0.18	50%
Test site (D ≥ 200m)	67.8%	0.29	56.6%

Application: “millions craters” catalog project

Mars Express High Resolution Stereo Camera (HRSC) image # 905, resolution 12.5 m/pixel, 35,495 identified craters

818 km 65448 pixels



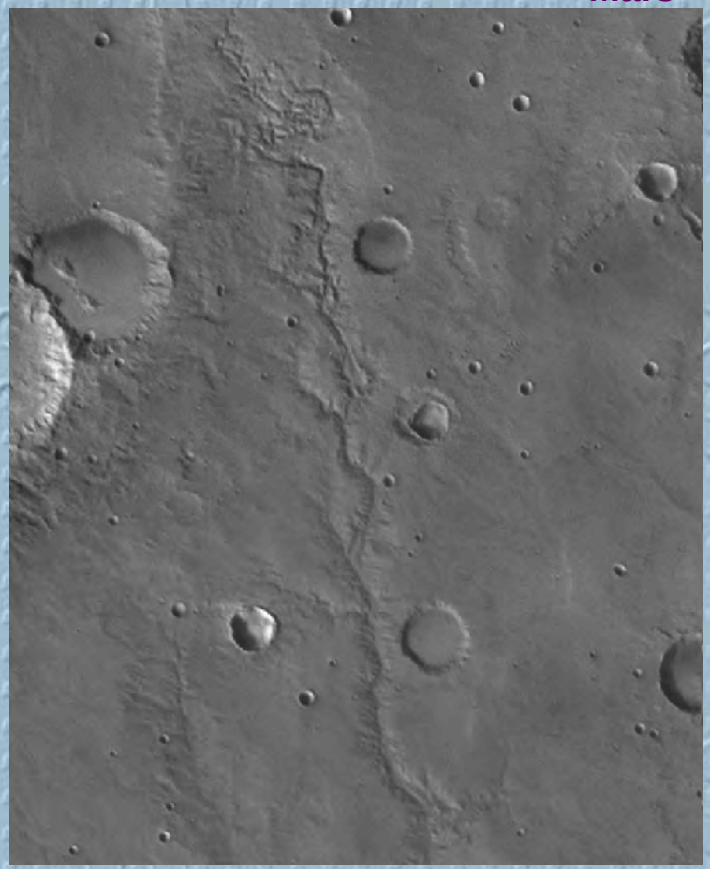
Summary for mapping sub-kilometer craters from images

- Mapping code is still in development. Improvements in accuracy are needed.
- The "million craters" project of cataloging Martian sub-kilometer craters from HRSC images is feasible.
- Such catalog will a great tool for addressing surface ages and crater degradation processes.
- The method works on any planetary images. The size of detected craters depends on the image resolution. About 20 pixels are needed to detect a crater.

Martian Valley Networks

- Similar to terrestrial river systems.
- Thought to be carved by runoff or groundwater flow.
- Can provide a glimpse into the hydrological conditions of early Mars

Mars

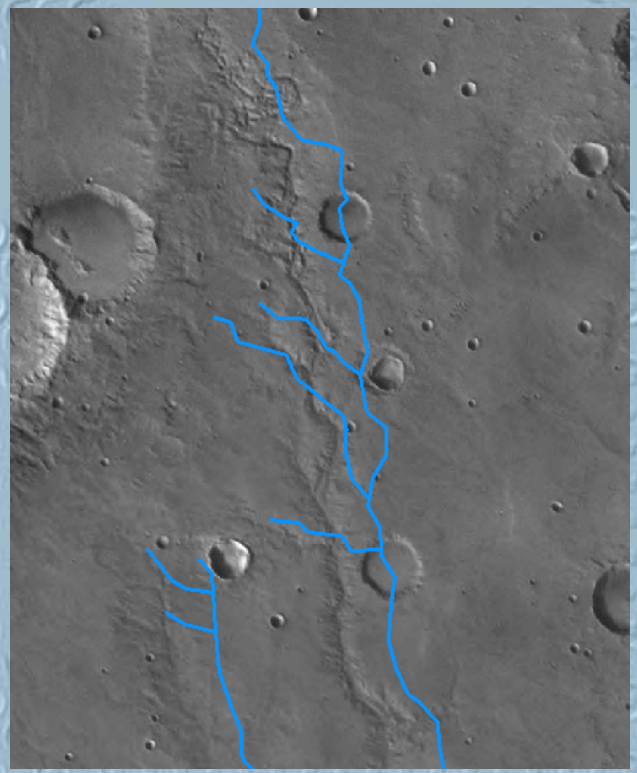


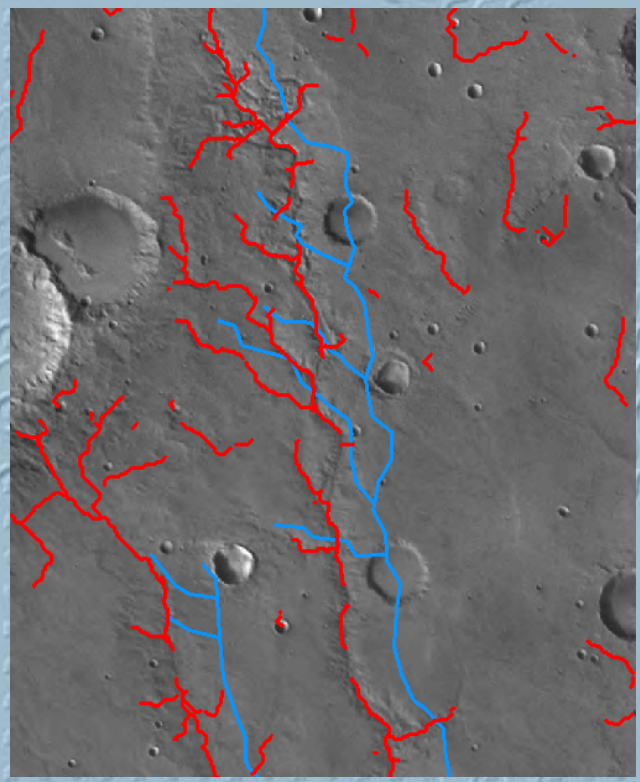
Earth

Martian Valley Networks

- Manually created global database from Viking orbiter images (Carr 1995)
- Incomplete
- Not coregistered with modern spatial datasets
- Topographically incorrect
- We need a new database
- Problem: Manually drawing in valleys for entire Mars is just plain ridiculous

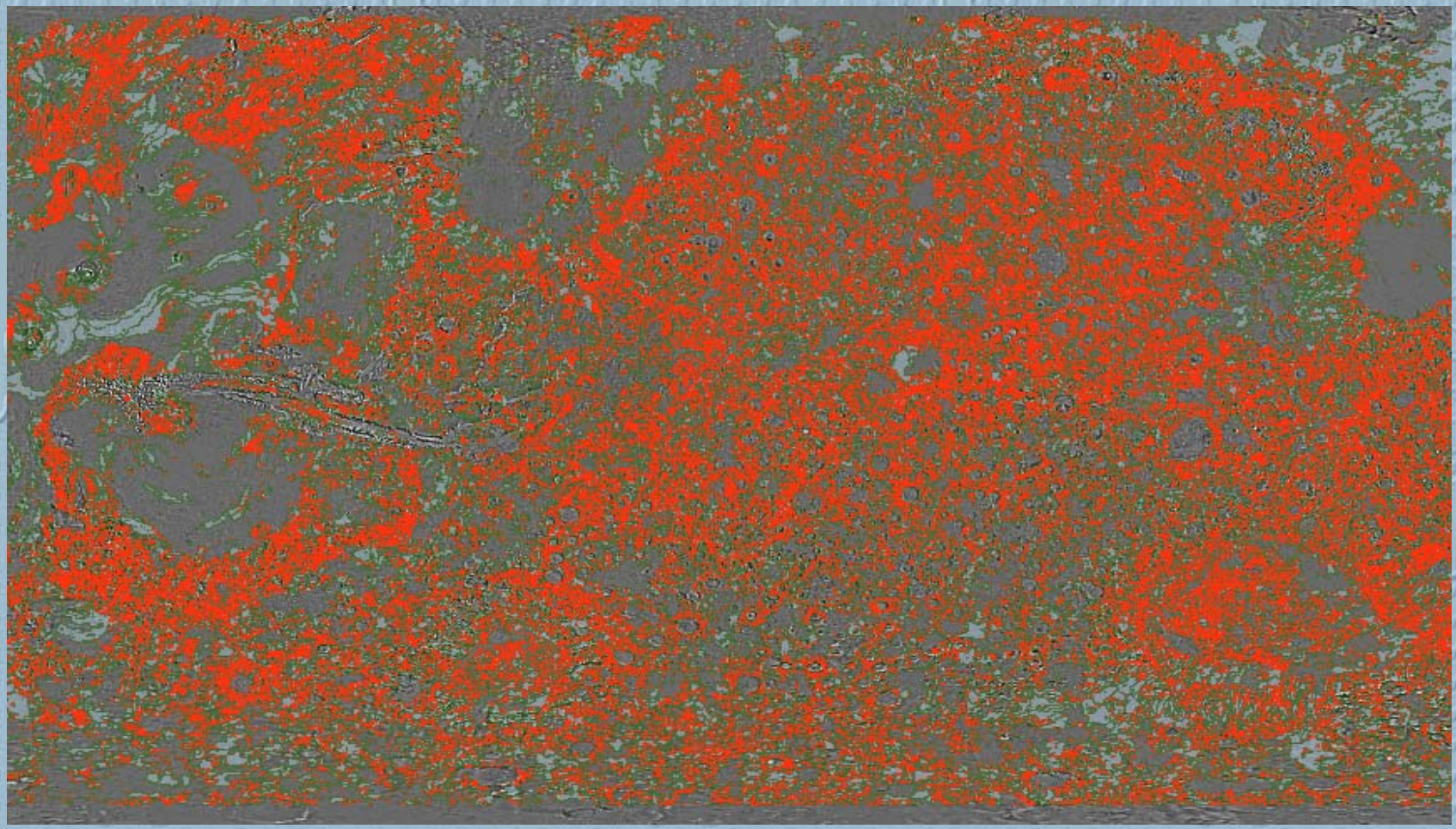
- Solution: Automatic mapping from topography
- Much faster
- Less accurate, many false positives
- Heavily segmented
- Useful for researchers manually working on smaller areas
- How to refine the database?





Building a database

- Scan the 458,000 segments and identify which should be connected into networks
- Use ArcGIS functions to create watersheds (drainage basins) for each network and segment
- Take in all of the available information and read in or calculate values of hydrological importance for each network



Networks attributes

Identified network →

- ID
- Are loops present?
- Outlet (x,y)
- Source elevation
- Outflow elevation
- # Segments
- Order
- Magnitude
- Length
- Length of main stream
- Area of drainage basin
- Sinuosity
- Slope
- Aspect
- Bounding box
- Location by geological unit

Machine learning

→ Valley network

→ Not valley network

Summary for mapping valley networks

- Mapping code has been developed and is in the public domain.
- The code has been delivered to two researches to be used for terrestrial applications.
- The code is offered as a Web Service within a framework of GeoBrain. The purpose of this service is to provide everyone with the capacity to extract valley networks (or river systems) using our novel method. Our Web Service can be test driven at http://65.123.203.154:8099/OnAS/.
- The database of valley fragments has been calculated.
- Machine learning algorithm needs to be applied to this dataset to obtain a final global map of Martian valley networks.